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14. ABSTRACT

The research objective of this project is to explore ways of covertly delivering interventions into the adversary decision cycles so as to effectively shape adversary decision-making and performance without inducing much suspicion. The technical approach is to design a set of interventional schemes, and evaluate, both empirically and computationally, their effectiveness and robustness on escaping detection and disrupting performance. Recognizing that completely covert interventions, while most effective, are difficult to implement, in the current phase of the project, we focus on a more general mode of covertness. That is, instead of delivering completely hidden interventions, we deliver interventions that may be noticeable but whose true meanings are hidden or distorted (e.g., the operators do not easily attribute the interventions to malicious attacks). This approach, based on insights from human abductive reasoning rather than straightforward attentional manipulations, is easier to implement and potentially more powerful. In the past years, we have taken steps to evaluate the approach in simple empirical settings and have obtained promising results. See our renewal proposal for more information.

15. SUBJECT TERMS

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Final Performance Report
FA9550-07-1-0181

This report is part of the renewal proposal submitted to AFOSR. It summarizes the results we have obtained so far.

Attentional manipulations

Attention is the first cognitive faculty we have explored in our attempt to understand covert interventions. On the one hand, there is no better way to implement covertness than designing interventions that are invisible even to the adversary operator's attentional system. In this case, the interventions are completely hidden and therefore can potentially cause most and long-term damage. On the other hand, a large body of evidence in the field of psychology has shown that attention is a fragile function that is subject to exploitation and manipulation. Our exploration with attention-based covertness started with a taxonomy of attention. A recent theoretical breakthrough of attention research is the notion that there exist different types of attention, each of which is subserved by different brain regions and is sensitive to different variables (Fan, McCandliss, Sommer, Raz, & Posner, 2002; Posner, 2004). Alerting (for general preparatory attention), orienting (for selecting subset of information for further processing), and executive control (for monitoring and resolving conflict in planning and decision-making) have been distinguished at both functional and brain levels. Equipped with the taxonomy, we suggested that each type of attention could be subject to different exploitations for the purpose of covertness. We systematically explored and identified a set of manipulations that could be used, including attentional blink, inhibition of return, change blindness, the order effect, negative priming, and etc. We conducted studies to examine the effect of parameter changes on inducing covertness in order to find the optimal delivery schemes (Fan et al., 2009; Sun, Wang, Zhang, & Smith, 2008; Wang & Fan, 2007).

Stealth and disruption with IMPs

As a preliminary step toward abduction-based covertness, we conducted a study to examine how a human operator digests unexpected interventions and adjusts his level of suspicion. The study utilized Interface Manipulation Protocol (IMP), which was developed by our collaborators at AFRL at Rome. The toolbox of IMP contained dozens of possible intervention types that could be delivered to the adversary computers to cause disruption with, for example, keyboard and mouse operations. How to configure the chain of IMPs (e.g., when to deliver what IMP for how long?) to cause maximal disruption with minimal suspicion raised a challenge.

In the study, subjects were instructed to type in sequences of random numbers as prompted (Figure 1), where 3 types of IMPs were silently delivered (by hijacking the subject's keyboard). Subjects were then asked to evaluate the "reliability" of the input device.

Figure 1. Subjects were required to reproduce the target sequence. Errors were prompted in red color and need to be corrected with extra keystrokes. Errors could included “IMP errors” (produced deliberately by IMPs) and “genuine errors” (subjects’ own typos).

The study included several independent variables, including:

- 3 types of IMPs
  - non-responsive key: when a key is typed nothing shows up, so the subject has to retype to correct;
  - repetitive key: when a key is typed the key shows up twice (e.g., typing “3” and “33” shows up), so the subject has to erase the extra number;
  - altered key: when a key is typed a different key shows up (e.g., typing “3” and “4” shows up), so the subject has to erase the wrong key and retype.
- 4 types of delivery themes
  - Pure: only one type of IMPs is delivered in a particular trial.
  - Mixed: multiple types of IMPs are delivered in a particular trial.
  - Clumped: IMPs are delivered consecutively.
  - Dispersed: IMPs are delivered sparsely.
- 4 levels of IMP delivery rates (10%, 20%, 30%, 40% of the garget characters are affected by IMPs).

There were two major dependent measures. Stealth (covertness) was measured by the subjective evaluations of the reliability of the input device. Higher evaluation scores indicated higher tolerance of IMPs and therefore less suspicion. Disruption was measured by the number of extra keystrokes (“ExtraKS”) required to complete the sequence (excluding the extra keystrokes directly caused by IMPs). Higher scores of ExtraKS indicated more severe disruptions to the performance. The goal was to find an optimal delivery strategy that caused maximal disruption with maximal stealth.

One main result of the study is shown in Figure 2, which depicts the effect of delivery themes on stealth and disruption. It is clear that in terms of stealth the mixed-clumped delivery (IMPs with mixed types are delivered continuously) is the best and that in terms of disruption the pure-dispersed delivery (IMPs with the same type are delivered sparsely) is the best. Further analysis shows that if we combine the two dependent measures, the pure-dispersed delivery has the highest effectiveness score.

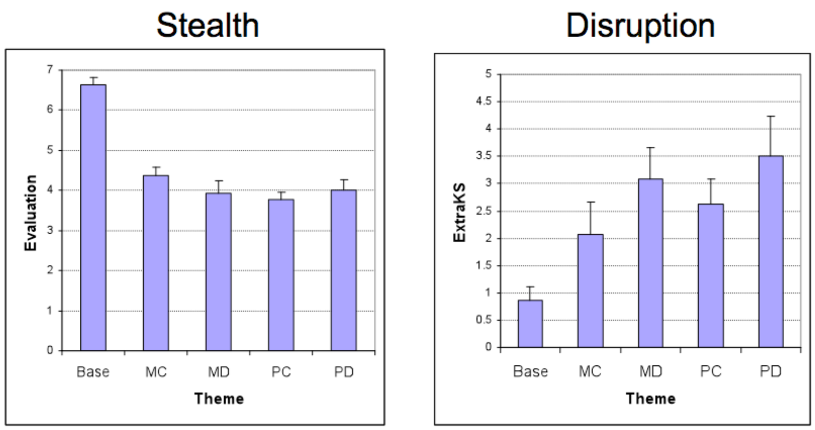

Figure 2. The effect of delivery themes (Base: no IMP was delivered; MC: IMPs were delivered in mixed-clumped fashion; MD: mixed-dispersed; PC: pure-clumped; PD: pure-dispersed).

DURIP 2008 award

We are also happy to report that we have obtained a DURIP 2008 award thanks to the support from AFOSR associated with this project. The award allowed us to purchase an eye-tracking system (Smart-Eye, www.smarteye.se) that could be integrated with our existing neuroimaging system (128-channel EGI system, www.egi.com) and powerful experimental design system (E-prime, www.pstnet.com). The integrated system (Figure 3), the first in the US, is capable of collecting temporally synchronized high-resolution eye-movement data and neural electroencephalography (EEG) data, which is ideal for the purpose of the current project, where one goal is to monitor human suspicion and study how suspicion is modulated by interventions.

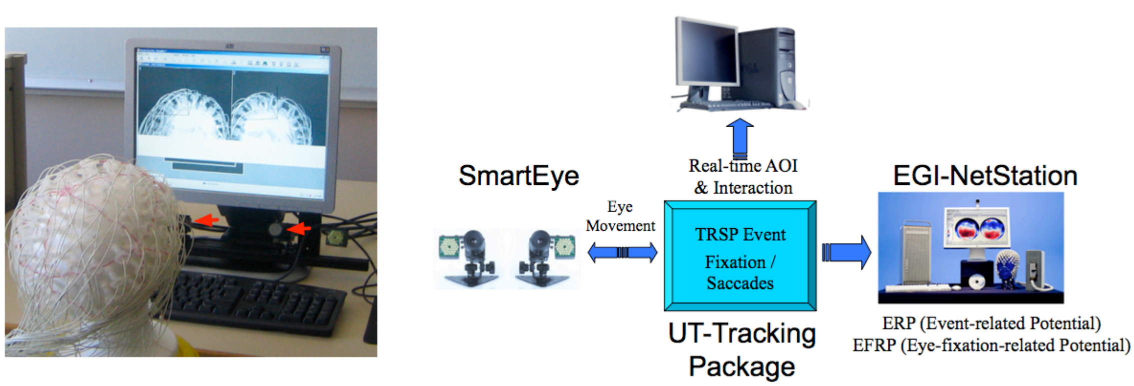

Figure 3. Left: the integrated experiment system (a head wearing a 128-channel EEG net, red arrows points to the two eye-tracking cameras). Right: via the UT-Tracking package we developed, we integrate the systems together and gain unique capabilities including real-time fixation analyses, AOI association, interaction / gaze control.

Recently, we have developed a software package named UT-tracking to fully realize the function of the integrated system (Figure 3). The package allows more seamless integration of different sub-systems and offers unprecedented capabilities for multi-mode data collection and analysis. Some capabilities include:

- Real-time eye / mouse movement tracking and fixation analyses (independent or integrated tracking).
- AOI (area of interest) association.
- Real-time eye gaze interaction and gaze control.
- Synchronization with higher-level behavioral measures.
- Easy integrations with neuroimaging data collection – fixation and AOI results can be used to segment EEG.